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A CRITICAL REVIEW OF THE LITERATURE OF 1956 ON WATER POLLUTION

M. B. Ettinger, et al

Robert A. Taft Sanitary Engineering Center
Cincinnati, Ohio

February 1957

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Prepared for the Research Committee
of the

FEDERATION OF SEWAGE AND INDUSTRIAL WASTES ASSOCIATION
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Public Health Service

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BIOLOGY

Pollution Surveys

A survey of several rivers in India indicated damage to fisheries by wastes from chemical works, paper mills, sugar refineries, and by the discharge of sewage. Remedial measures have been suggested, but there is no pollution legislation in India (24). In reporting upon a survey of Birmingham streams, Hawkes (72) points out that biological characteristics are of importance in determining the effects of a pollutant. The character of the stream community reflects the "effective" pollution and avoids the complications involved in strictly chemical or physical standards. The effect of pollution can range from a slight shift in the proportions among the natural population to a complete alteration of the entire range of life forms. He found that the biological method tends to give an average pollution indication, whereas chemical sampling gives only a "spot" result.

A survey of the upper Rhine (49) indicated that Lake Constance is of great importance in supplying well oxygenated water to the river. In spite of heavy pollution above the lake, the phytoplankton in the lake insures well aerated water. Downstream, conditions for the development

of plankton become increasingly unfavorable due to increase in turbidity and decrease in D.O.

Surveys of environmental conditions in estuaries have shown that their capacity for self-purification is not as great as is commonly believed. Studies made in Wellington Harbor, New Zealand, showed that M.P.N. figures alone are not satisfactory for surveys of an area where old sewage may be returned by wind and tide. It was found that wind is the dominant factor in the dispersion of the sewage, tide playing only a minor part (91). Studies of the bottom materials of the lower San Gabriel River of California demonstrated the deposition of materials having either a sulfide or petroleum odor. No living organisms were noted in these deposits, but after cleaning by dredging, 12 species of marine invertebrates became established. However, within 2 years after excavation there was evidence of the formation of new deposits (142).

In connection with studies in British estuaries, Southgate and Gameson (160) propose two standards for the management of rivers. One would limit the concentration of particular constituents in an effluent, and the second would be a measure of the effect which the effluent would have on a river. These effects could be measured by bio-assays with fish, and B.O.D. studies. It is pointed out, however, that the normal 5-day B.O.D. test does not necessarily indicate the total effect of the effluent on the stream as nitrification may occur shortly after discharge and the ratio of the ultimate O_2 demand to the 5-day B.O.D. varies widely. The rate at which O_2 is dissolved from the air also depends on the type of stream. Synthetic detergents markedly reduce the rate at

which O_2 is absorbed from the air by deoxygenated water. It is recommended that in estuaries in which D.O. is approaching the critical level, remedial measures be undertaken before anaerobic conditions develop. Studies are now in progress on the anaerobic digestion of strong organic waste waters, such as those from slaughter houses.

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Fish Kills

The Aquatic Life Advisory Committee of the Ohio River Valley Sanitation Commission has prepared a booklet on procedures for the investigation of fish kills. Various possible causes of fish kills are discussed and methods for their investigation outlined. The importance of prompt investigation, thoroughness of coverage, and the use of biological indicators are stressed. The use and value of bio-assays for the determination of toxicity are also outlined (10).

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Stream Environments and Water Quality Criteria

General

The second progress report of the Aquatic Life Advisory Committee of ORSANCO deals with temperature, dissolved solids, settleable solids, chloride, fluoride, color, and D.O. It is concluded that for a well-rounded warm water fish population in the Ohio River, peak water temperatures should not be raised above 93° F. at any time; during the period December through April water temperatures should not be raised above 73° F., and further, temperatures in streams suitable for trout should not be

increased. It was recommended that bio-assays be used to determine the degree of dilution essential for the safe disposal of brines and other complex wastes high in dissolved solids. Due to lack of definite information, no criterion was formulated on the amount of settleable solids which could be added to a stream. It was pointed out, however, that the deposition of any material on a gravel rubble bottom reduces productivity. It was recommended that no organic wastes be added to streams in such quantities that they alone or in combination with inorganic material form sludge beds or change the physical nature of the bottom. It was suggested that chloride ion concentration has in itself no practical significance as far as aquatic life is concerned. It was recommended that fluoride ion concentration be limited to levels found safe for human consumption. In regard to color, it was considered desirable to restrict the addition of any substance to natural waters that reduces the productivity of aquatic plants through lessening of light penetration.

Suspended Solids and Turbidity

In Europe, many industries are discharging turbid wastes into streams with resulting turbidity and the blanketing of the stream bottom. Among these are dusts and inorganic wastes from metal working and mining industries, iron-ore-crushing plants, blast furnaces, rolling mills, talc and magnesium plants, and coal mines. The iron ore crushing plant at Erzberg-Eisenerz has a waste containing 5000 p.p.m. suspended solids, while coal and lignite washings from mines have 1000 to 5000 p.p.m. These wastes blanket the stream bottom and destroy food producing areas

(165). During the war, when industry was shut down, the streams cleared up and recovered.

The rivers Mur and Murz in Styria are heavily polluted with industrial waste waters. Wastes are of two types, those from iron and mining. One of the most damaging materials is fine clay, which is not removed in the settling pits and damages the turbines of power works downstream. Materials which settle out make the bed of the stream almost sterile. In addition, $Fe(OH)_3$ from pickling wastes is precipitated on the eggs and gills of fishes with lethal results. Waste waters from mining and the treatment of iron ore produce turbidity over long stretches of stream (166).

Studies made in Mill Creek, a tributary of the Sacramento River, indicated that a severe loss of king salmon eggs occurs during incubation due to silt and stream erosion (59). Eggs placed in a channel free from silt had a survival rate 4 times as high as those subject to silting (60).

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Temperature

Studies carried out at the Hunt Creek Fisheries Experiment Station in Michigan have shown that impoundment by a beaver dam raises the water temperature significantly. When the average water temperatures for the three years previous to impoundment were compared with those for the three years following impoundment, it was found that the average had increased 10.1° F. for June, 8.8° F. for July, and 6.5° F. for August (154). Results of acclimation tests indicated that the upper tolerance temperature for a species depends to some extent on the temperature to which it is acclimated. Channel catfish acclimated at 22° C. died a few hours after exposure to 35° C.; while those acclimated at 30° C. were all alive after 24 hr. of exposure to 35° C. Under conditions of continuous exposure, channel cats died at 32° to 33° C. Bullheads survived temperatures of 34° C. It is suggested that most temperate zone streams should not be raised above 30° C. for prolonged periods (21).

In all fish studied, the upper lethal temperature was below 40° C. regardless of acclimation. High temperatures decrease resistance to toxic materials. Because there is severe competition for space, a species may be eliminated by an unfavorable but not lethal temperature. Thus, optimal temperatures should be of more concern than those of bare survival. Variations of 4° C. in either direction from the optimal 26° C. will slow growth of Nitzchia filiformis (22). Other species have an even narrower range of tolerance.

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Dissolved Solids and pH

Drainage from strip mining slag piles was found to be lethal to fish in dilutions of 1 in 50 (111). Acid in the drainage from mines is produced by bacteria in the presence of air and water (169). A survey of three strip-mine areas in southern Illinois under both summer and winter conditions indicated no relation between age and the condition of the water, at least between the ages of 4 and 30 years. The majority of the ponds were slightly basic, but some were extremely acid. The most common fish found in the bonds were green sunfish, bluegill, and largemouth bass. Many ponds were devoid of fish, and it was concluded that possibilities for the production of fish in strip-mine ponds are limited. This is due to acidity, high salt content, and low fertility (112). Studies of the median toxicity thresholds of 10 fresh water fishes to oil well brines indicated a range in the values from 4.3 to

11.2 per cent of the brine from a single well. Median toxicity thresholds for 10 invertebrates ranged from 1.8 to 8.7 per cent of the brine (33).

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Dissolved Oxygen

Experiments carried out in a spring near Welaka, Florida, showed that Gambusia and Mollienesia could not survive at a D.O. level of 0.3 p.p.m., unless they were allowed to gulp air at the surface (132). It was found that while young sturgeon can live and grow at D.O. concentrations below 5 to 5.5 p.p.m. at 18° C., O_2 concentrations of that amount and above are required for optimum growth (118). Studies of 6 fishes from Uganda showed that the hemoglobin of the blood of different species varied in its ability to take up O_2 at different levels of O_2 saturation and at different CO_2 concentrations. The hemoglobin of Tilapia esculenta shows considerable affinity for O_2 which allows that fish to survive under conditions which would cause severe respiratory distress in others (57). For young sturgeon 1.5 to 7 months old, the critical O_2 level, that is, the concentration below which O_2 uptake decreases, varied from 1.8 p.p.m. at 11° C. to 6.0 p.p.m. at 28° C. Threshold concentrations, that is, the level at which O_2 uptake fell to zero, varied from 1.4 p.p.m. to 3.1 p.p.m. over the same temperature range (117). A survey of environmental conditions in Osborn Bay near Crofton, Vancouver Island, showed that surface discharge of the pulp mill effluent inshore would result in O_2 levels too low for a healthy oyster population. It was recommended that the effluent be discharged at a depth of 10 fathoms and far enough outside the bay to allow adequate

dilution and dispersal by strong currents (177). Studies on the Main and Danube throughout the year indicated that the effects of putrefiable wastes on D.O. were less in free-flowing than in impounded stretches, but reduced D.O. levels extended over a greater distance in the flowing stream (2). Studies of polluted pools containing plant life showed that frequently the magnitude of photosynthetic reaeration equals or exceeds that produced by atmospheric contact. The photosynthetic factor can be very high in small rivers. The O_2 balance is calculated from data on daily level of D.O. only if the amount of D.O. in the whole water column is known and its variation throughout the day can be determined. Calculations based on purely locally drawn samples are unsatisfactory (176). Death of fish in the Fox River was attributed to the presence of algae by an anonymous author. It was stated that the D.O. fell from 3.05 p.p.m. at 6:00 P. M. to 0.4 p.p.m. at 6:00 A. M., and on the following day rose again to 3.3 p.p.m. (3). The author overlooked the fact that organic pollution is generally the cause of excess algal growth, that bacteria as well as algae respire at night, and that without the photosynthetic activity of the algae, D.O. levels would be low, both day and night. Further, if the photosynthetic activity of an excess population of algae cannot raise the D.O. content above 3.3 p.p.m., it is evidence that there is a great putrescible waste load being broken down by bacteria.

Laboratory experiments have indicated that the presence of anionic synthetic detergents reduce the rate of solution of O_2 through the surface. Experiments were made in a stream and it was concluded that detergents reduce the rate of entry of oxygen into the water (174).

Lac de Brot, originally oligotrophic, has undergone a steady eutrophication with a well developed thermocline and a long-continued stagnant hypolimnion during the summer months. Artificial sub-lacustral aeration added 9 to 10 metric tons of O_2 to the hypolimnion and removed 8-9 tons of CO_2 and thus reduced productivity so that eutrophication was arrested. This removed the Fe problem in the water supply and brought about a change in the plankton (125). It was found that the toxicity of non-ionized NH_3 increased as the D.O. decreased. Further, a solution containing NH_3 and synthetic detergents was more toxic than solutions containing each of the two substances individually. A concentration of non-ionized NH_3 equivalent to 0.2 p.p.m. N decreased the survival time of trout at a D.O. level which otherwise had no lethal effect. There was also a definite interaction between D.O. and CO_2 (75).

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Toxicity

General

Studies of the toxicity of nine inorganic salts to Daphnia magna clearly indicated that a reduction in the D.O. below 4.5 p.p.m. reduced the resistance of the daphnia to the toxic materials (56). The Fish and Wildlife Service Laboratory at Kearneysville, W. Va., has made toxicity screening tests with 735 compounds made available by the Chemical-Biological Coordination Center. Tests were made in constant temperature aquaria at concentrations of 5 p.p.m. with brown trout, bluegill, yellow perch, and goldfish. Times for sickness or death are listed in hours (107).

Bio-assays are now being used not only to determine the toxicity of materials but also to determine the quantity of a toxicant present or to detect its presence in very small quantities which cannot be determined chemically. Shaw and Lawrance (153) used bio-assays for the estimation of metal ions. They prepared progressively diluted aliquots of an unknown solution containing the cation to be estimated. Then the toxicity of these aliquots for the test organism (guppies) was compared with the toxicity of standard solutions containing the same cation and the concentration of the unknown calculated. This procedure approaches the accuracy of the most refined chemical techniques and allows a great saving in time and cost. A similar technique has been used for the quantitative estimation of the molluscicide, sodium pentachlorophenate, in natural waters. The test requires evaluation of mortality rate curves for specific dosages

covering the range of conditions to be encountered in the field. Quantitative field determinations are obtained from a comparison of the unknown with the standard mortality.curves. This method gives reliable results necessary for effective molluscicidin; operations (96).

Another approach to the toxicity problem has been proposed by Halsband and Halsband (68). They believe that the effects of poisons and waste waters on fish should not be measured by the death or overturnin, of fish in aquaria but by the pathological effects. Using the method with trout, the boundary for phenol was 1.3 p.p.m. Greven (65) reviewed the methods for determinin; the effects of toxicants on fishes and tested several methods. He discussed the expression of results used by different workers and recommended that lethal limit be defined as the concentration which causes death of a given type of fish with 24 hr.

According to an account given by Czerkinski (39), extensive studies are under way in Russia for determining the permissible concentration of toxic and other harmful materials in surface waters. Thirteen investigators examined 30 toxic and otherwise harmful materials and presented tables listing permissible concentrations and decisive tests. The standards proposed have been adapted as legally binding.

The Metals

In most previous investigations, the toxicity of Fe has not been adequately separated from the effect of the low pH brought about by the Fe salts. La Roza (101) has attempted to overcome this difficulty in his studies by using iron lactate. He was able to observe in very low concentrations of Fe, the entrance of the Fe into the gills. There appeared

to be no resistance to the entrance of Fe in the cation form but anionic iron penetrates only after death, and, therefore, does not have a toxic action. Death does not occur before about 2 hr., regardless of the concentration of Fe. If before this time the fish are placed in pure water, the iron leaves the gills. Poisoning by Fe is a reversible phenomenon which can be explained by an impregnation of the gills. With solutions containing 1 p.p.m. Fe, it can be removed in 8 hr.; for 2 p.p.m. the period is 12 hr.

Studies of the toxicity of copper sodium citrate, $HgCl_2$, HgI_2, and ethylmercuric chloride to the crustaceans Artemia salina, Elminius modestus, and Acartia clausi, indicate that Artemia is the most resistant. Differences in resistance were also greatest for Artemia. Mixtures of the copper salt and $HgCl_2$ showed more than additive toxic effects. Artemia exposed to sublethal doses of Cu are rendered more susceptible to poisoning by the Hg salts. The reverse is also true (36).

Saitzeva reports (146) that his experiments are in agreement with the suggested maximum limit of 0.1 mg. of Pb per l. in water supplies for consumption. There is also a suggested limit for fishes in some waters. Experiments have indicated that concentrations of less than 20 p.p.m. CrO_4 prevent multiplication of sulphate reducing bacteria, but that they have a bacteriostatic rather than a bactericidal action (48). Studies carried out by the Washington Department of Fisheries Laboratory have indicated the relative toxicity of several metals in fresh and salt water. Minimum lethal concentrations in p.p.m. of the following were found to be: $BaCl_2$ 148 p.p.m.; hexavalent chromium, less than 10 p.p.m. in fresh water, 17.8

p.p.m. in sea water; trivalent chromium, 50.0 p.p.m. in fresh water, more than 50.0 p.p.m. in sea water; Cu $(NO_3)_2$, 0.18 p.p.m. as Cu in fresh water, and 0.56 p.p.m. as Cu in salt water; and lead acetate, 2.8 p.p.m. as Pb in fresh water (63). It should be realized that these results are applicable only for the particular dilution water used.

The effects of $MnCl_2$ and $MnSO_4$ on fish, crabs and fish food organisms were determined by means of bio-assays. With $MnSO_4$ the first adverse effects were noted at a concentration of 500 p.p.m. and death occurred at 1000 p.p.m. With $MnCl_2$ the first effects were observed at 333 p.p.m., while a concentration of 400 p.p.m. produced mortality. Sphaerium, dragonfly larvae and Cambarus affinis were apparently undamaged at concentrations of 1000 p.p.m. (119). In studies to determine the toxicity of magnesium salts to guppies and Tilapia macrocephala, it was found that resistance increased with age. For guppies the toxicity threshold was 8000 p.p.m. in the dilution water used, while for Tilapia, it was 1000 p.p.m. (7).

Cyanide

Complexing has been suggested as a method for the disposal of cyanides. In some instances this may be helpful but in others it is not. Zinc cyanide and cadmium cyanide complexes proved to be exceedingly toxic. Synergism of the toxic metallic ions and cyanide liberated through dissociation of the complex ions is indicated. Combination of Ni and cyanide into a complex resulted in a marked reduction of the toxicity of each. Concentration of free cyanide only, in undiluted cyanide bearing waste waters, is not a reliable measure of the pollutional potency

of the waste. Metal-cyanide complex ions, including the relatively stable nickelo-cyanide ion must be regarded as potential sources of toxic HCN (45). It has been shown that in concentrations of KCN between 0.07 and 0.25 p.p.m. the log period of survival of rainbow trout decreased linearly with increases in log concentration of poison (74). In discussing the cyanide problem in Britain, Pettet and Ware state that the toxic effect on fish of a cyanide concentration above 0.018 to 0.025 p.p.m. precludes the discharge of waste waters containing cyanide in inland watercourses (137).

Phenol

Phenolic waste waters cause loss of fish due to the removal of oxygen from the water, the repelling of the fish, toxic action, the tainting of fish flesh, and the destruction of food organisms (12). It has been found that phenol kills Tubifex worms at a minimum concentration of 200 mg. per l., but 150 mg. per l. were not lethal in 5 days (66). Studies in Germany indicated that the various phenols in combination have an additive effect but generally they do not occur in concentrations lethal to fishes. Among the substances tested para-xylenol was the most toxic (18). Several of the phenolic compounds cause the tainting of fish flesh at concentrations far below those lethal to fishes. Chlorophenol is especially bad for the tainting of fish flesh. It is concentrated in the fatty tissue of fish and oysters and, while man can detect it at 1 part in 100 million, these animals can acquire noticeable tastes from waters containing as little as 1 part in 10^9 parts of water (14).

Ammonia

Investigations directed toward obtaining information on the effects of the concentration of D.O. on the toxicity of NH_3 were carried out at D.O. concentrations of 1.0 to 9.0 p.p.m. Solutions containing unionized ammonia equivalent to 1.96, 1.38, and 0.86 p.p.m. N were used at a pH of 7 to 8 and a temperature of 19.8° C. Results showed that the periods of survival of trout increased as the concentrations of D.O. increased, that at each D.O. concentration the period of survival decreased as the concentration of unionized ammonia increased, and that the effect of O_2 in increasing survival time was greatest in the lower concentrations of unionized ammonia (47).

Detergents

The British Committee on synthetic detergents concluded that the anionic surfactant now in greatest use does not appear to be readily or completely destroyed by existing sewage treatment methods; that rivers receiving these effluents are adversely affected with respect to their ability to support healthy fish and plant life, and their suitability for drinking water (143). Studies were made of the toxicity of synthetic detergents to fishes with special reference to the substances in the commercial products other than the surface active agents. It was found that the following had little or a low level of toxicity: sodium sulphate, sodium silicate, sodium tripolyphosphate, sodium pyrophosphate, and sodium perborate. A fatty alkylolamid killed all fish in 24 hrs. at a concentration of 24 p.p.m. (8). Studies made by Mann indicate the detergents act on the epithelium of the gills and skin. No tainting

of the flesh was noted. Tests were also made with Leonil AR, an anionic-active product on an alkylaryl sulphonate basis, on fish food organisms, Tubifex, Chironomus, Carinogammus, and Asellus. Tubifex was most resistant and Chironomids most sensitive. Detergents were toxic at concentrations of 10 to 25 mg. per l. Concentrations up to 10.7 mg. per l. have been found in crude sewage. Therefore, the effects on the aquatic fauna must be considered (121).

Oil Refinery Wastes

Investigation of a stream receiving oil refinery wastes indicated that the typical color and odor of the effluent persisted as far as 18 miles downstream where the dilution was twentyfold. The D.O. was eliminated in the stream. The number of species of aquatic organisms recorded was 32 above the refinery and 11 below (32). Experiments with different chemicals occurring in oil refinery waste waters have shown that many of them can clarify turbid waters characteristic of the southwest. Some clarified the water at levels which were non toxic to fishes but the required levels for others were toxic (180).

Paper Mill Wastes

The avoidance reactions of juvenile chinook salmon and coho salmon to waste from sulphate and sulphite process pulp mills, and the reaction of steelhead trout to sulphate waste were investigated by means of a modified gradient tank. Chinook salmon showed marked avoidance of sulphate waste; coho salmon showed much less avoidance; and steelhead trout showed none. Chinook salmon showed avoidance of 10, 5, and 2.5 per cent of the waste in

dilution water. Coho showed little avoidance of waters containing 10 per cent of the waste (91). Bio-assays of cellulose waste waters showed that a dilution of 1 part waste in 800 parts water was lethal to goldfish in 24 hrs. A dilution of 1 in 2000 caused discoloration of the skin and, for safety, a dilution of 1 in 3000 was chosen. When the waste water was neutralized, the toxic material was precipitated (94). The toxicity of the waste water from the sulphite cellulose plant was also determined for the algae, Scenedesmus obliquus. The most toxic component of the waste was identified as pitch abietic acid (95).

Insecticides

Bio-assays were conducted to determine the toxicity to rainbow trout of seven insecticides; chlordane, heptachlor, aldrin, dieldrin, toxaphene, methoxychlor, and DDT. They were tested as emulsions, wettable powders, and dusts. Fish were exposed for 24 hrs. to concentrations of 0.05, 0.1, 0.25, 0.5, and 1 p.p.m. of the various materials. Toxaphene and dieldrin were the most toxic, while chlordane and DDT were generally least toxic (163). Two barge loads of chlorinated hydrocarbons were dumped in 100 fathoms of water about 100 miles south of Galveston. Bacterial counts showed little injury to bacterial populations, but blue-green algal photosynthesis was inhibited. Zooplankton studies did not show excess toxicity, but the sea anemones were affected (84). Fresh water animals on the Island of Cyprus have been devastated by DDT spraying for the eradication of mosquitoes (163).

Advances in chemical technology have resulted in the development of over 100 effective insecticides. These materials fall roughly into two

groups, namely, the chlorinated hydrocarbons and the organic phosphates. The former are more stable, retain their toxicity over much longer periods, and are far more lethal to fish. Golden shiners are among the most resistant fishes to insecticides, while bluegills, largemouth bass, and goldfish show increasing sensitivity in the order named. TDE and BHC are the safest of the chlorinated hydrocarbons for the fishes. Crustacea and many of the aquatic insects are more sensitive than fish, while mollusks are more resistant. Generally, dieldrin, toxaphene, heptachlor, aldrin, endrin, and methoxychlor are more toxic to fish than DDT or chlordane, while EPN, BHC, and TDE are less toxic, with TDE and BHC being the least toxic. However, BHC causes the tainting of fish flesh when used at concentrations of 1 pound per acre (161). A bibliography of references on the harmful effects of insecticides, algicides, and herbicides to aquatic organisms, other than those they were designed to control, has been prepared by Ingram and Tarzwell (88).

The toxicity of rotenone to yellow perch was studied under laboratory conditions and toxicity curves were constructed. This fish is killed at low concentrations as is the brown trout (20). Pentachlorophenate used as a molluscicide for the control of the snail hosts of schistosomes is quite toxic to fishes at concentrations as low as 6 p.p.m. Aquatic insects of importance as fish food are also killed (97).

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Putrescible Wastes

Effects of Organic Enrichment

An investigation of the effects of the discharge of large volumes of treated sewage to a lake near Copenhagen indicated that it resulted in the production of a large amount of phytoplankton. In July, almost 10 gm. of carbohydrates were produced per sq. meter per day (129). In a Study of Lytle Creek, it was found that the length of the creek chubs, Semotilus a. atromaculatus, of the same year class differed significantly in the various pollutional zones. They were smallest in the stretch of stream above the sewage outfall and largest in the lower portion of the recovery zone, the difference being about 20 per cent (93).

An investigation of the behavior and relation of nutrient materials in oligotrophic and eutrophic lakes lead to the conclusion that in oligotrophic lakes little nutrient matter returns from the sediment, while in eutrophic lakes a much greater part of the nutrient matter returns to solution. Nitrogen compounds are redissolved in much greater quantities than P compounds and thus, the addition of a waste rich in P may suddenly convert an oligotrophic lake into the eutrophic type (172). Lake Washington has been receiving increasing amounts of treated sewage and appears to be responding by changes in kind and quantity of biota. There has been an increase in the

O_2 deficit in the hypolimnion and an increase in the phosphate concentration (50). As shown by other investigators, the concentration of minerals present in sewage-works effluents can cause excessive algal blooms in lakes. It is suggested that the nutrient materials be removed from the lake in the form of algae which can be used as fertilizer (159).

Laboratory experiments indicated that a continuous discharge of spent sulphite liquor was most favorable for optimum growth of Sphaerotilus natans. In order to control or reduce Sphaerotilus growths in the river, intermittent discharge of spent sulphite liquor was initiated with a discharge interval of less than 6 hrs. It was thought that this reduced the growths in the river (1). The soluble phosphates in the effluent from a secondary treatment was found to supply ample nutrients for the growth of algal blooms in Lake Zoar in Connecticut. There was a succession of different dominant species as the seasons progressed: Oscillatoria, Microcystis, Anabaena, Spirogyra, and Hydrodictyon (38). The critical concentration of P for blue-green algae is stated to be 0.01 p.p.m.

Indicators of Organic Enrichment

In a study of the Elbe from the outlet of the Hamburg harbor region to Kugelbake, it was found that the degree of pollution was clearly recognizable by the communities of organisms present(11). In general, those organisms most favored by a given environment will be most numerous while those adapted or adaptable to the widest environmental range will occur in the greatest number of samples. The species found in greatest number probably indicate a response to some particular characteristic of the environment. Specific meanings of various populations are listed by Lackey

(99). A modification of the commonly recognized life zones in polluted streams has been suggested by Sramek-Husek. It is to divide the polysaprobic zone of Kolkwitz and Marsson into 4 groups, one or all of which may not be present in a particular stream. These are: 1. antisaprobic - high concentration of toxic industrial wastes and all life absent; 2. hypersaprobic - an area of highly fermentable fresh wastes, B.O.D. 500 p.p.m. or above, and biota characterized by great masses of yeasts; 3. a-polysaprobic - a zone with B.O.D. between 100 and 500 mg./l. and biota of bacteria and achromatic flagellates; and 4. B-polysaprobic - characterized by a B.O.D. between 10 and 100 p.p.m. and a biota consisting of Sphaerotilus, polysaprobic flagellates, Tubifex, some Chironomidae, and Eristalis (162).

Many springs in Florida are deficient in D.O. Oxygenation is rapid, but definite zones are established in which organisms are found in accordance with their D.O. preference or requirements. Forms generally considered as tolerant of organic enrichment are found in the spring heads (157).

Seibold investigated the effects of certain sewage decomposition products in Planaria, oligochaetes, leaches, and insect larvae. In these studies which continued for as long as 21 days, indole, skatol, histamine, putrescine, cadaverine, and hydroxylamine were used. It was found that skatol, indole, and hydroxylamine were most toxic, while histamine, putrescine, and cadaverine were less toxic, being harmful at levels of about 30 mg./l. These materials are more lethal at higher temperatures. The degree of sensitivity of the various aquatic organisms is related to their rank in the saprobic system (150).

In studies of the effects of sewage pollution on Lytle Creek, chemical and physical conditions were related to the qualitative and quantitative

composition of the aquatic populations found in the different "pollutional zones." It is pointed out that little reliance can be placed on any one species as an indicator of organic enrichment. It was found that in clean waters there was a great variety of organisms, usually gilled forms, none of which occurred in great abundance. In the recovery zone there were fewer species, usually those having several methods or organs for respiration. In the septic zone the population was represented by only a few species, but by large numbers of individuals, all of which were adapted in one way or another to survive at very low D.O. levels (62).

In Louisiana, it was found that studies of aquatic populations were essential for determining the pollutional status of some streams. It was observed that the aquatic populations were indicative of the pollutional zones (34).

A total of 94 species of Diptera were collected from Lytle Creek in southwest Ohio. Diptera are found in many different environmental niches in both clean and organically enriched water, and many are highly selective in in their habitat preference. Those species with special adaptations for obtaining O_2 from the water surface, such as the larvae of the families Culicidae, Syrphidae, and Stratiomyidae, occurred frequently in large numbers in the septic and recovery zones. Representatives of the family Chironomidae are adapted to many different habitats in the stream, with several species showing a marked selection for specific environmental niches in each of the life zones. The presence of Chironomus riparius, Glyptotendipes sp., Eristalis bastardi, and Culex pipiens in large numbers was characteristic of the septic and upper recovery zones, and their abundance in other similar

streams may be interpreted as an indication of organic enrichment. Species restricted to definite and narrow habitats constitute much better indicators than those species adaptable to a range of conditions. Clean water species are in general more reliable indicators of environmental conditions (134).

Comparative studies of three streams gave evidence that quantitative and qualitative determinations of the suspended algae and protozoa provide specific evidence of the fertilizing effects of a treated sewage effluent. Recent fecal pollution appears to be a factor favorable to stimulating blooms of certain species of Euglenophyceae, while the same environment appears to be limiting for some species of Chrysophyceae (98).

Brondyke states that careful study of a stream's diatom population and their distribution gives a reliable criterion of the water's ability to support aquatic life. The Sabine River was surveyed by the use of a "diatometer," and improved pollution control methods were based on the results obtained (17).

Effects of Impoundment

The amount of self-purification is an essential point in assessing the quality of stream water. Damming a stream alters the original population including the fish life. In streams of good condition, dams do not have an adverse effect on self-purification. Heavy pollution, however, has a great effect on the condition of the water (113). The construction of large dams in the Tennessee Valley has caused major environmental changes in the streams below the dams, including lower average temperatures, erratic seasonal D.O. patterns, and great daily fluctuations in water velocity and volume (138).

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MICROBIOLOGY

In 1955 water was definitely incriminated in only two disease outbreaks in this country (42). One was in fire fighters who filled canteens from water tanks previously used to pump cesspools. All continued their duties. The other outbreak was in a school where 22 were ill. The water supply was from a well contaminated by a septic tank and E. coli was recovered from the well water. One large outbreak of infectious hepatitis including over 7,000 cases occurred in New Delhi, India (41) and was attributed to the treated municipal water supply which was heavily contaminated with sewage before treatment. Another small outbreak of infectious hapatitis occurred in Austria (135).

LeMaistre, et al (106) reported the epidemiological aspects of a water-borne outbreak of amebiasis that occurred in South Bend, Indiana in 1955. A membrane filter procedure for the demonstration of E. histolytica

in contaminated water was described by Chang and Kabler (26). By this method, 50 per cent positive cultures were obtained from one-gallon samples if the initial cyst concentration was 5 cysts per gallon. Observations on the survival of Shigellae in sewage (181), of Leptospira australis in soil and water (158), of human tubercle bacilli in polluted waters (77, 78), and of Coxsackie virus (30) in water and sewage clearly demonstrated that all these organisms survive for considerable times in polluted waters and must be considered in water treatment practice.

Stevenson et al. (164) developed a method of concentrating dilute virus suspensions by alum flocculation which detected as little as about 0.006 LD_{50} per 0.02 ml. of original sample. Metzler, Ritter and Culp (126) showed the combined process of plain sedimentation, coagulation, settling and rapid sand filtration, as practiced in conventional water treatment plants, completely removed all viable spores of H. capsulatum, even without chlorination. Cooke, Moore and Kabler (35) studied 8 species of fungi, commonly isolated from sewage, that were able to compete successfully with other microorganisms for organic materials in solution and for oxygen available in the dissolved state. Significant reductions in dissolved oxygen were observed in the first 4 days at pH 2.9.

The physical, chemical and biological composition of submerged slime growths in sewage and polluted waters were discussed by Heukelekian and Crosby (79, 80). They also studied effects of environmental conditions on slime formations. Joseph (92) described taste and odors and a purplish pink color in a service reservoir that were caused by a colored sulphur bacterium identified as Rhodocapsa species. It was assumed that gulls feeding at the sewage works and resting on the reservoir at night were

responsible. The role of Ferrobacillus ferrooxidans in stream recovery from acid bituminous coal mine wastes was reported by Leathen et al. (103). Eventually the iron was deposited as a brownish yellow sludge in the stream, while the stream itself remained acid.

Enteric organisms in sea water and tidal estuaries (133, 64, 130, 16, 90, 188) usually suffer high mortalities in the first few hours, but a few cells may survive a month or more. Interactions of salinity, sedimentation, predation by higher forms, sunlight, bacteriophage, biological activity, etc., contribute to bacterial deaths. The comparative viability of pathogens appears similar to nonpathogens, however, this relationship is still not adequately defined.

Peso and Mignone (136) and Ware and Mellon (182) did not find bacteriophage a useful indicator of water pollution. Willis (186, 187) concluded that anaerobes do not provide a useful index of fecal pollution of water because they are widely distributed in soil and that many of the anaerobes found in water are derived from the soil.

Symons (167) discussed physical and chemical disinfectants, the disinfection reaction and factors influencing the reaction. In comparison of ozone and chlorine as water disinfectants, Hann (69) reported that ozone was more effective when applied in similar dosages. Using radioactive chlorine, Friberg (58) found 10 to 25 per cent of the free available chlorine used up was in the bacterial cells after 5 min. exposure to 0.5 p.p.m. free available chlorine. No significant difference was demonstrated in the amount of free chlorine absorbed by E. coli and Staph. aureus. Heicken (73) described the chemical reactions occurring in chlorination of sewage, the

hydrolysis equilibrium and the reactions of chlorine with ammonium. There was no linear connection between oxidation potential and bactericidal action. Clarke, Stevenson and Kabler (31) showed that purified type 3 adenovirus was inactivated by chlorine in amounts similar to that required for inactivation of E. coli and S. typhosa. Chambon and Vigne (25) considered chlorination the only practical means of sterilizing sewage from hospitals for infectious diseases. For complete sterilization it was necessary to allow contact for 2 hrs. and 20 mins. with 56 mg. of chlorine per l. Lowe et al. (116) reported the destruction of microorganisms in polluted water, sewage and sewage sludge by ionizing radiations in dosages from 7.5×10^4 to 2.0×10^6 rad. No correlation between the physical strength of various bacterial cells and their susceptibility to the lethal effect of freezing could be demonstrated (173, 70).

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Differential bile-salt tests at 44°C. for the detection of fecal contamination in water was found more rapid and convenient by Buczowska (19) than conventional lactose fermentation tests. Emmenegger (52) preferred formatericinoleate medium over MacConkey medium for testing river water for the presence of E. coli. Of the various antibiotics tested by Dianova and Voroshilova (44), gramicidin C, and streptomycin were the most satisfactory for the isolation of typhoid and dysentery organisms from river water. In testing Potomac River water, Gunther and Fisher (67) secured higher coliform counts in lauryl sufate broth containing 10 units of penicillin per 5 ml. of broth than without penicillin. They stated that the penicillin stimulated the growth of coliform organisms and inhibited growth of many other forms. Shipe and Fields (155) suggested the use of a chelating agent, tetrasodium

salt of ethylenediamine tetra acetic acid, for maintaining the coliform index in water samples during transportation from collection site to the laboratory.

In considering methods of reporting coliform density, Hopkins and Schamberger (86) found the geometric mean more desirable for comparing bacterial characteristics of one stream with another, and in comparing conditions in one stream from month to month and year to year. Walton (179) presented data showing that adequately designed and well operated water treatment plants can treat raw waters heavily laden with coliform organisms to produce effluents conforming to the bacteriological requirements of U.S.P.H.S. drinking water standards. These results indicate that current U.S.P.H.S. recommendations with respect to the density of coliform organisms in raw waters acceptable for treatment are no longer applicable in modern well operated plants. Ritter, Shull and Quinley (144) showed a positive association between coliform and enterococcus groups in well waters in Kansas, and that tests for enterococci would be useful in addition to tests for coliform organisms. Dardanoni (40) has confirmed the usefulness of azide medium for the isolation of enterococci from polluted and potable waters.

Macris (120) has proposed a rapid nitrite test for use in estimating the number of coliform organisms in water. Rawn and Bowerman (140) have summarized the advantages and disadvantages of the membrane filter test for coliform organisms in water and Enslow (53) and Eliassen (51) have pointed out its potential as a water control method and suggested its use as an alternate standard. Thomas et al. (171) have reiterated these recommenda-

tions and proposed a code to be used with membrane filter results. Hope and Neill (85) demonstrated the feasibility of using membrane filter field test laboratories in determining the bacteriological quality of drinking water supplies in national parks. Hirsch (81) reported that MF procedures were highly accurate and time saving in clearance testing of new pipelines. Additional information on the effects of media, temperature and humidity on the development of coliform organisms by MF technics has been reported by Eye, Gardner and Neel (55). McCarthy (124) concluded that discrepancies between MF and tube technics appeared to increase with time and distance from fresh pollution and that difficulties of recovery increased with ratio of noncoliform to coliform organisms. Using a combined method of membrane filtration and electronmicroscopy, Scarce (148) observed 68 to 75 per cent correlation of electron microscope readings and standard methods MPN.

Levin et al. (110, 109) have developed a radioisotope technic for the rapid detection of coliform organisms. A water sample was filtered on a one-half inch membrane filter using a syringe adapter. The filter was placed in a planchet with 0.1 ml. of 1 C^{-14} lactose. The planchet was placed in an apparatus and aerated, thus collecting radioactive CO_2 as barium carbonate. The emissions of CO_2 were counted in a modified Robinson gas-flow counter with a commercially available scaler equipped with amplifier. Positive results have been obtained from small numbers of coliform organisms after as little incubation as 10 mins. and a total elapsed time of 25 mins. Because of several unexplained biological vagaries, more developmental research is needed.

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CHEMISTRY

Toxicological items of interest are reported here largely because they may not fit in under other headings of this review. Decker and others (43) made preliminary report on the effects of 0.1 to 10 p.p.m. of cadmium and 1-25 p.p.m. of chromate (as chromate ion) on animals. Possible adverse effects were noted only with 25 p.p.m. of chromate. These preliminary results are held to be tentative pending completion of long time exposure tests. Cass (23) discussed the philosophy of approach and the proposed program of the ORSANCO-Kettering Water Toxicity Project.

The interaction of complex self-purification mechanics and water quality was considered in a number of papers. Skopintsev and Krylova (56) studied the stabilization of a "water humus" added to river water in the form of planktonic organisms. In 160 days the complex organic matter was largely destroyed or reduced to inorganic carbon. Bogan and Sawyer (15) made further report on the interrelationship of chemical structures and susceptibility to biochemical oxidation. Vinberg, and others, (176) discussed the oxygen balance in photosynthetic systems and enumerated the many variables involved in studying oxygen relationships therein.

Huet, and others, (87) studied oxygen transformations in the Hain and Geer Rivers, including consideration of photosynthesis in their studies.

Ettinger (54) discussed biochemical stabilization mechanisms and stressed the importance of the chemicals resistant to biochemical stabilization in determining stream water quality. Middleton, and others(127), presented data on the interrelationships of organic pollutants and the taste and odor problems in processed drinking water at Nitro, West Virginia which uses Kanawha River water a few miles below the chemical producing area at Charleston, West Virginia.

Schmidt (149) presented an exhaustive study of the contamination of ground water by nitrates in Minnesota. In general, the high nitrate ground waters were associated with soils of high nitrogen content and/or soils receiving high surface loads of nitrogenous material, such as animal manure.

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OXYGEN SAG AND STREAM SELF-PURIFICATION

Another statistical method for evaluating the self-purification capacity of a stream has been presented by Churchill and Buckingham. (27) The method of analysis avoids the use of the velocity constants k_1 and k_2 for deoxygenation and reoxygenation. Instead, it involves making a statistical fit of observed data according to the assumed relation:

$$D.O.\ drop = a + bL(5) + cT + \frac{d}{Q} \qquad (1)$$

where the D.O. drop is the difference, in ppm, between the D.O. at a location above the single pollution source and the D.O. at the critical point of the sag curve; L(5) is the 5-day BOD in p.p.m. measured at a location in the vicinity of the critical point; T is the water temperature in °C.; Q is the stream flow in cfs, and a, b, c, d are constants to be determined by statistical analysis of the data obtained from a set of observed D.O. profiles. Once these constants are derived, they are used to predict critical D.O.'s under reduced pollution load conditions. The significance of the observed relationship is tested by multiple correlation techniques.

The form of equation (1) is of particular interest in that it assumes a separate simple linear relationship between D.O. drop and each of the variables. While this is not in conformity with the familiar oxygen sag equation, it may be a useful approximation.

In applying equation (1) to an existing situation the 5-day B.O.D. was measured at a location quite far downstream from the pollution source (in fact, downstream of the critical point) in order to minimize the variability of this factor and thereby improve the overall correlation

coefficient. The relation between the B.O.D. downstream and the B.O.D. immediately below the pollution source was then derived and tested by statistical analysis. The resulting B.O.D. equation permitted estimates of the B.O.D. reduction at the downstream location due to waste treatment at the source. This information, used in equation (27), yielded predictions of the improvement of the critical D.O. resulting from various degrees of waste treatment. It must be noted, however, that the derived B.O.D. equation predicts substantial gain in B.O.D. at the downstream point as against an upstream unpolluted location even though one assumes 100 per cent B.O.D. removal at the source by waste treatment.

For satisfactory application of his method of analysis the author estimates that about 18 or 20 sets of data and D.O. profiles will usually be needed. If these data do not result in a sufficiently high correlation coefficient he indicates that more samples will be necessary. It is further indicated that the observed data should include a considerable range in each of the variables, and that D.O.'s should be observed simultaneously at all sampling stations in order to minimize the effects of photosynthesis. A similar discussion based upon the same observed data has been presented by Churchill (28, 29).

A general discussion of some of the factors involved in the self-purification of inland streams and tidal estuaries has been presented by Southgate and Gameson (160). Special attention has been given in this article to the management of rivers, biochemical oxygen demand, rate of atmospheric reaeration, bottom deposits, and effects of synthetic detergents. Reaeration is discussed in terms of the "exit coefficient," f, which is

related to the reaeration velocity constant, K, by

$$f = \frac{VK}{A},$$

where V is the volume undergoing reaeration and A is the exposed surface area. These authors have found exit coefficients for shallow turbulent streams to be as much as 200 times as great as the values found for nearly stagnant water. Synthetic detergents had very little effect on f in nearly stagnant or very turbulent water, but resulted in as much as a 50 per cent reduction in f for streams of intermediate turbulence. There is no discussion or note of the effects on f of photosynthesis and respiration of algae.

On the basis of general theory of turbulent flow O'Connor and Dobbins have developed equations for evaluating the rate of atmospheric reaeration in natural streams (131). It is shown that in turbulent flow reaeration occurs as the result of molecular diffusion of oxygen through the gas and liquid films at the air-water interface, and thereafter by eddy diffusion (mixing) throughout the main body of liquid. Molecular diffusion through the liquid surface film is the slowest of the processes involved, hence it is the governing process in atmospheric reaeration. As a result, the rate of reaeration is a function of the rate of surface renewal due to turbulence, i.e., the frequency or speed with which liquid surface elements are presented to the atmosphere.

These considerations, together with evaluation of the rate of surface renewal under various flow conditions, have led to the development of

theoretical expressions for k_2, the reaeration velocity constant. The relationship between the rates of reaeration and surface renewal was tested experimentally in the laboratory and verified. As further verification, values of k_2 computed by the derived equations have been tested against values reported in the literature from field studies of the Illinois, Clarion, Ohio, and other rivers. The values from field studies of others were selected for river stretches thought to be reasonably free of sludge deposits and algae. There was good agreement between computed and observed results.

Investigations on the Willamette River (147), a stream deficient in nitrogen, have led to interesting conclusions regarding the availability of nutrients and rates of biochemical oxidation. It is reported that in nitrogen deficient streams the rate of oxidation of organic material may be significantly affected by the degree of pollution loading. In such cases, reduction of the pollution load can result in a more favorable B.O.D. to nitrogen ratio and thence to an increased rate of biochemical oxidation.

Several general reviews of factors involved in stream self-purification have been published in foreign journals, (13, 104, 105) and Vinberg has reported results of studies on the effects of photosynthesis in polluted waters (176).

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STREAM STUDIES AND SURVEYS

Investigations and studies of watercourses are receiving due emphasis as result of basin-wide water resource conservation and development programs. Water pollution, as it affects the basic water resource, is becoming increasingly important.

Cramer, Johnson, Ferguson, Metzler, Detweiler and Ramsey (37) discussed the ramifications of the Missouri River water resource conservation and development program. This comprehensive evaluation included (1) Reservoir building, (2) Bank stabilization, (3) Flood control, (4) Irrigation, (5) Navigation, (6) Hydro-electric power, (7) Improvement in water supply, (8) Water treatment problems, (9) Sources of pollution and pollution abatement, (10) Chemical analyses of Missouri River water. Hoak and Bramer (82) presented three methods for estimating the load of suspended solids in streams. The method employed will depend on the quantity and quality of available data, location, accuracy desired and available time. Laboratory and field studies were made by Heukelekian and Crosby (79) to evaluate the influence of certain factors on slime formation in treated effluents after various degrees of purification, and in stream waters. It was concluded that the degree of roughness of the submerged surface does not affect ultimate quantity of slime growth; aerobic environment produces more slime than anaerobic conditions; nature and concentration of food effects slime growth, and low velocity during primary slime formation period increased growths although higher velocities after the initial period induced greater growths. Vavasour and Blair (175) studied pulp mill polution in an arm and a tributary of Notre Dame Bay, Newfoundland; they concluded

that the wastes were not present in sufficient quantities to be harmful to fish life. A reconnaissance of chemical and physical quality of Pryor Creek in Oklahoma, reported by Dover and Murphy (46), presented analyses of 69 samples collected at 9 stations over a 4-month period; pollution resulted from paper mills and a fertilizer plant. Numerous studies of the effects of water conservation and reservoir construction on rivers and stream pollution have been conducted by interested State and federal agencies. Such reports are available, no doubt, from the responsible agency.

The effects of pollution on harbor waters received considerable attention. Maxwell (122) conducted a year's study of hydrobiological conditions in Wellington Harbor, New Zealand, observing temperature, tidal activity, fresh water run-off and effects of pollution consisting of oil and refuse from ships, city sewage, and effluent from a meat freezing company. Pulp mill pollution in Alberni Harbor, British Columbia, was investigated by Waldichuk (178) who concluded that discharge to surface was a good recommendation as advantage is taken of seaward flow and high D.O. in the surface water. There is possibility of toxicity, and not just oxygen demand, after plant expansion has been completed. Larson (102) conducted a factual survey and investigation of sewage and industrial waste disposal in Los Angeles and Los Angeles and Long Beach Harbors. Based on this study, the Los Angeles Regional Water Pollution Control Board adopted a long range waste disposal and water quality objectives. New York Harbor geography and sampling procedures used by the New York City Department of Public Works are described by Shapiro (151). Romer (145) discussed the health department's interest in bathing and shellfish growing waters of

New York City Harbors. It was found that coliform densities increase dramatically after heavy rains, making it necessary to evaluate the safety of Jamaica Bay waters for bathing after summer rainfall that might occur twice a week. Average daily coliform densities cannot be used, as short time (6 hours) densities may be excessively high. Ingram (89) studied methods of treating cabin cruiser toilet wastes and concluded that grinding and chlorination reduced coliform densities and produced wastes that could be discharged without serious health hazard or nuisance.

Valuable water quality data have been collected by the United States Geological Survey. Love (114) reported on over 100 river stations in 10 southwestern states in the Lower Mississippi River and Western Gulf of Mexico Basins. Chemical analyses included silica, Fe, Ca, Mg, Na, K, HCO_3, SO_4, Cl, NO_3, and in most instances F, B, suspended sediment, temperature, pH, specific conductance and color. A report of the quality of surface waters for irrigation in western United States by Love (115) presented chemical analysis, chiefly salt burden, and other physical measurements for a network of stations west of the Mississippi River. Lamar, Krieger and Collier (100) reported the chemical quality, suspended sediment and water temperatures of surface waters of Kentucky.

The relationship of the chemistry of Minnesota surface waters and wildlife management was discussed by Moyle (128); the report gives ranges of pertinent chemical constituents: total alkalinity, SO_4, Cl, P, and total N. Two reports of chemical composition of Texas surface waters were issued by the Texas Board of Water Engineers (4, 5).

ABATEMENT AND CONTROL

The spotlight on water pollution control legislation centered on the passage of the Federal Water Pollution Control Act of 1956 by the 84th Congress (139). This Act is administered by the Surgeon General of the Public Health Service. The Act, as finally passed by Congress, reaffirms the policy of Congress to recognize, preserve, and protect the primary responsibilities and rights of the States in preventing and controlling water pollution. The Act authorizes grants to State and interstate agencies, up to $3 million per year for the next five years for pollution control activities, and $50 million per year for the construction of municipal sewage treatment works. It further authorizes increased technical assistance to States, a broadened research program, and the collection and dissemination of data on water quality relating to control of water pollution. The enforcement measures against the pollution of interstate waters, as originally provided for in P.L. 845, were modified and Federal installations were authorized to cooperate with State and interstate agencies or municipalities in preventing or controlling pollution from these sources.

Hollis and McCallum (83) have expressed the PHS Philosophy as that of supplying those services needed to complement the work of State and interstate agencies, communities, and industries in order to attain a well balanced national pollution control program. They point out the need for better public understanding to insure that the proper proportion of the municipal tax dollar will go toward the abatement of pollution. They estimate that, to make up the backlog of needed municipal works over the next ten years, and to take care of population growth and treatment plant

obsolescence, it will require doubling the average per capita expenditure now going into municipal construction, or about one-half billion dollars annually.

Weston (184) indicates that industry in the U. S. has spent at least $1 billion for water pollution abatement facilities, and estimates that from $4 to $5 billion additional will be necessary to control industrial pollution during the next ten years.

Hess (76), Watson (183), and Weston (185) all discuss the activities of industry in the field of industrial pollution control research. The need for development of improved analytical methods for analyzing industrial wastes, as well as research on methods for waste control, is emphasized. The authors pointed out that better information is required on quality indices and pollutional effects of specific wastes on receiving waters.

Municipalities are devoting increasing attention to the development of factors involved in the preparation and administration of municipal ordinances relating to the discharge of industrial wastes into municipal sewer systems. At Philadelphia, Reich (141) points out that pre-treatment requirements for industrial wastes are based on whether they will upset the operation of the plant, will damage sewerage structures, affect the hydraulic characteristics of the sewers, or will be harmful to maintenance and operating personnel. He emphasizes the need for good public relations with industry and the importance of working cooperatively with industry on their problems.

Taylor (168) speaking for Cincinnati, discusses industrial waste ordinances and the experience with adoption and enforcement of such ordinances

in that City. The Cincinnati ordinance, as ammended in 1953, provides for a maximum of flexibility with provision for separate rules and regulations controlling discharge to public sewers. The Cincinnati ordinance provides for a sewer service charge, with a surcharge on industrial wastes which impose an unreasonable burden on the sewage disposal system. It also prohibits any wastes which will damage the system or which cannot be treated satisfactorily.

Snaw (152) discusses the pros and cons of sewerage authorities, particularly from the standpoint of experiences in New Jersey. Advantages cited are: More rapid action, decreased financial liability to local governments, and relief of administrative burden on elected officials. The disadvantages indicated are: undue delegation of authority to a relatively independent agency and increased cost of financing as compared with municipal financing.

On the foreign scene it is noted that the Scottish Rivers Purification Committee (170) is being formed. The purpose of this Committee is to advise the Secretary of State on the cleanliness of waters, including tidal waters, to prevent the pollution of these waters, and to consider and make recommendations concerning the abatement and control of pollution. Southgate (160) reviews recent developments in the control of pollution in England, starting with 1927 when the Water Pollution Research Board was established. He mentions the two kinds of standards used in the control and prevention of pollution, namely, "effluent" and "stream", and cites reasons why the latter is preferred. He also points out that their studies indicate that the capacity of an estuary to purify sewage and trade wastes is much more limited than is often supposed.

STREAM STANDARDS

Garber (61) examined the status of bacterial standards for natural bathing waters. He found a wide variation in standards used, from essentially no coliforms to a median of <2,400 MPN per 100 ml. Authorities cited satisfactory epidemiological experience with standards throughout this range. Of numerous methods for measuring average or index values he selected the geometric mean as most applicable. The inadequacies of bacterial groups used as indicators of pathogenic contamination and the difficulties of reliable interpretation of the results obtained point up the need for improved methods. He concluded that unjustifiably stringent standards can lead to unnecessarily costly sewage treatment.

The California State Water Pollution Control Board (6) set numerical values to govern sewage discharge from the Los Angeles Hyperion plant. The order establishes three areas in Santa Monica Bay. All must be free of recognizable floating or suspended sewage solids. The outfall area, for dilution and dispersion, must have at least 6 p.p.m. of D.O. and grease shall not exceed 2 p.p.m. in 3, or 20 per cent in 20, consecutive samples. Coliform organisms in the beach area shall not exceed 10 per ml. in more than 20 per cent of the samples. In the intermediate area coliforms shall not exceed 100 per ml. and transparency, by the Secchi Disk, shall be at least 20 feet 50 per cent, and 15 feet 80 per cent, of the time.

Lester (108) reviewed development of English control legislation from the 12th century to the "River Boards and the Rivers (Prevention of

Pollution) Act, 1951." This Act empowers the 32 river boards to adopt by-law standards. It is assumed that by-law standards would apply only to existing sources of pollution. Consent of the boards, which may include individual standards, is required for discharge of new wastes. The trend is toward the Royal Commission on Sewage Disposal recommendation that a sewage effluent shall not contain more than 20 p.p.m. 5 day B.O.D. nor 30 p.p.m. suspended solids, and shall not exceed a specified volume. Industrial effluents should meet these requirements and also should be non-toxic to fish or fish spawning grounds, spawn or food for fish. The standards should not be exceeded in a single sample.

Hart (71) presented the case for stream standards as opposed to effluent standards. He recognizes, however, possible usefulness of effluent standards when a waste constitutes the entire flow of a stream, or when it becomes necessary to pinpoint responsibility of a recalcitrant polluter.

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